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(54) **DRILL STRING ROD**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,146,060 A * 3/1979 Garrett B23P 11/00 138/146
4,332,502 A * 6/1982 Wormald E21B 17/0426 403/343

(Continued)

FOREIGN PATENT DOCUMENTS

CN 107002467 A 8/2017
DE 2800887 A1 7/1978

(Continued)

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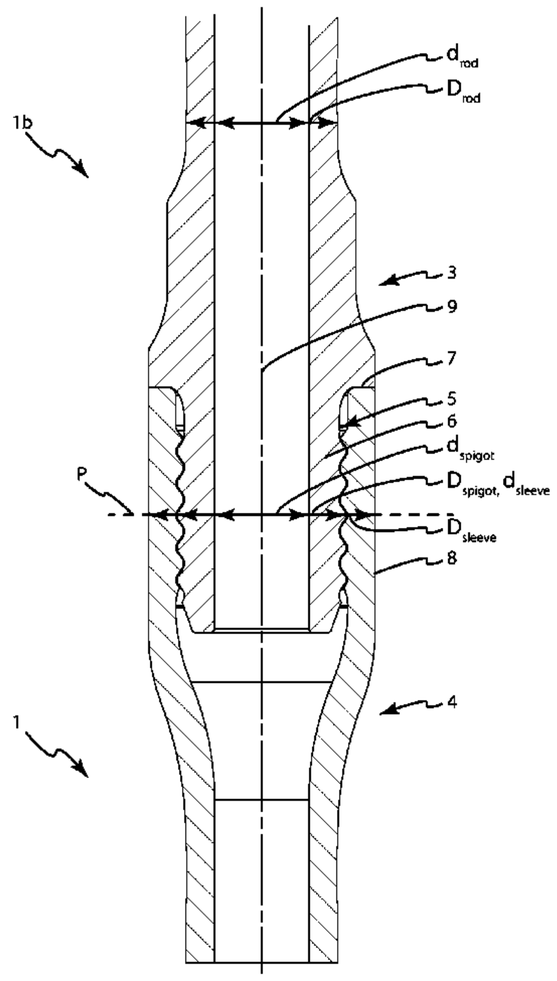
(57) **ABSTRACT**

A drill string rod includes an elongate central rod portion. The central rod portion has a hollow-cylindrical shape with an inner first diameter (d_{rod}) and an outer second diameter (D_{rod}). The male end includes a spigot having a base projecting axially from a shoulder that axially separates the spigot and the central rod portion. The female end has a sleeve portion that fits to the spigot. An inner thread of the sleeve portion is attachable to an outer thread of the base of the spigot of a further drill string rod. In a radial plane to the longitudinal axis of the drill string rod, the base of the spigot is defined by an outer third diameter (D_{spigot}) and an inner fourth diameter (d_{spigot}) and the sleeve portion is defined by an outer fifth diameter (D_{sleeve}) and an inner sixth diameter (d_{sleeve}), wherein the second diameter (D_{rod}) is >60 mm.

8 Claims, 2 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

4,398,756	A	8/1983	Duret et al.	
4,687,368	A *	8/1987	Eklof	F16L 15/006 285/334
5,236,018	A *	8/1993	Kobayashi	B29C 53/585 138/139
6,244,631	B1 *	6/2001	Payne	E21B 17/042 285/333
6,767,156	B1	7/2004	Larsson	
2005/0067195	A1 *	3/2005	Linden	E21B 17/0426 175/320
2005/0189147	A1 *	9/2005	Williamson	E21B 17/042 175/320
2010/0308577	A1 *	12/2010	Chin	E21B 17/042 285/333
2016/0208561	A1 *	7/2016	Ahola	E21B 17/0426
2016/0222737	A1 *	8/2016	Rosen	E21B 17/042
2018/0135782	A1 *	5/2018	Ahola	E21B 17/042
2019/0257970	A1 *	8/2019	Fang	G01V 1/44
2020/0173584	A1 *	6/2020	Biggerstaff	E21B 19/16
2020/0248509	A1 *	8/2020	Sugino	E21B 17/042
2021/0254414	A1 *	8/2021	Briane	F16L 15/001
2022/0290784	A1 *	9/2022	Cordero	F16L 15/002

FOREIGN PATENT DOCUMENTS

EP	2845992	B1	3/2015
RU	2204683	C2	5/2003
WO	0065192	A1	11/2000
WO	2015032657	A1	3/2015
WO	2015032659	A1	3/2015

* cited by examiner

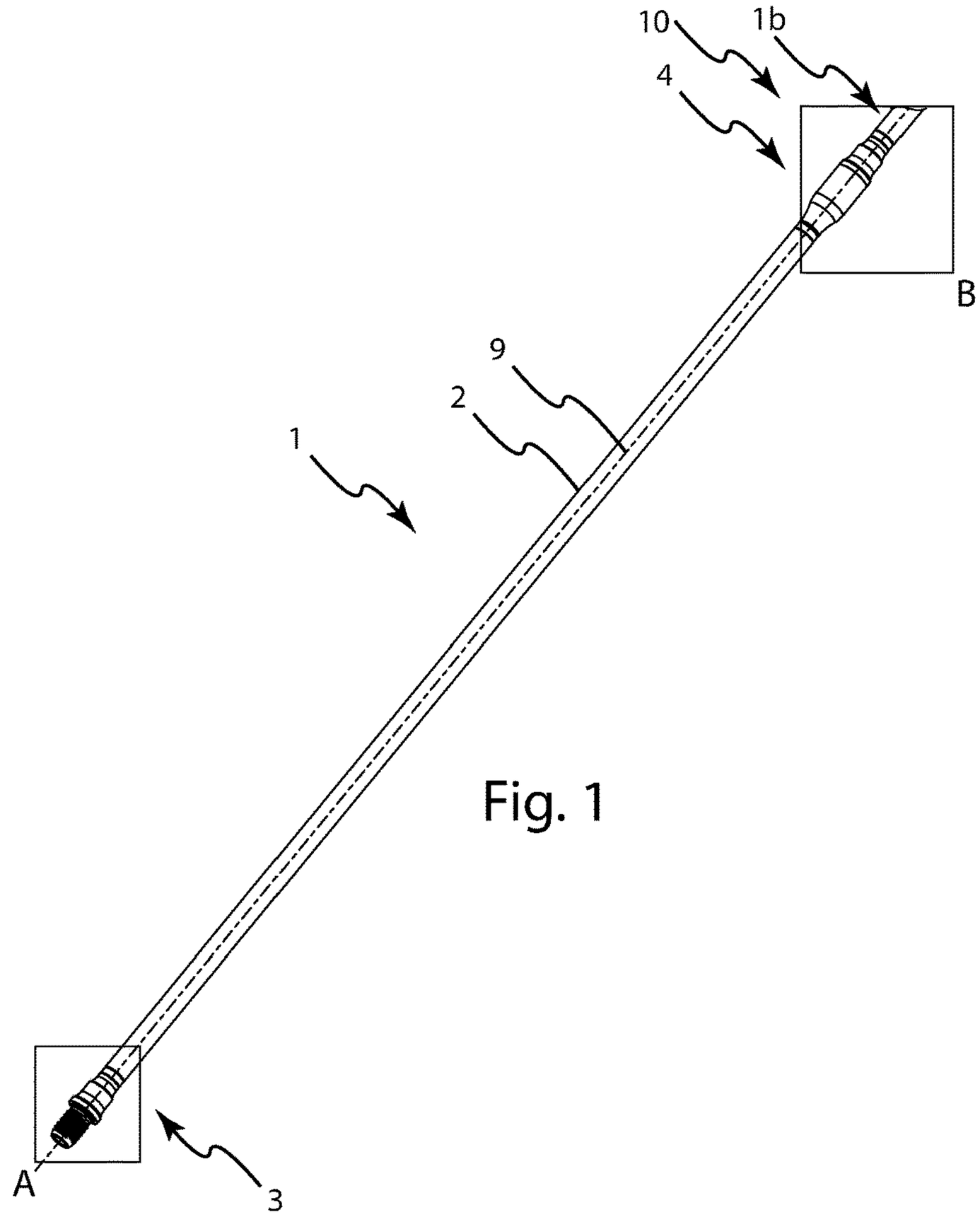
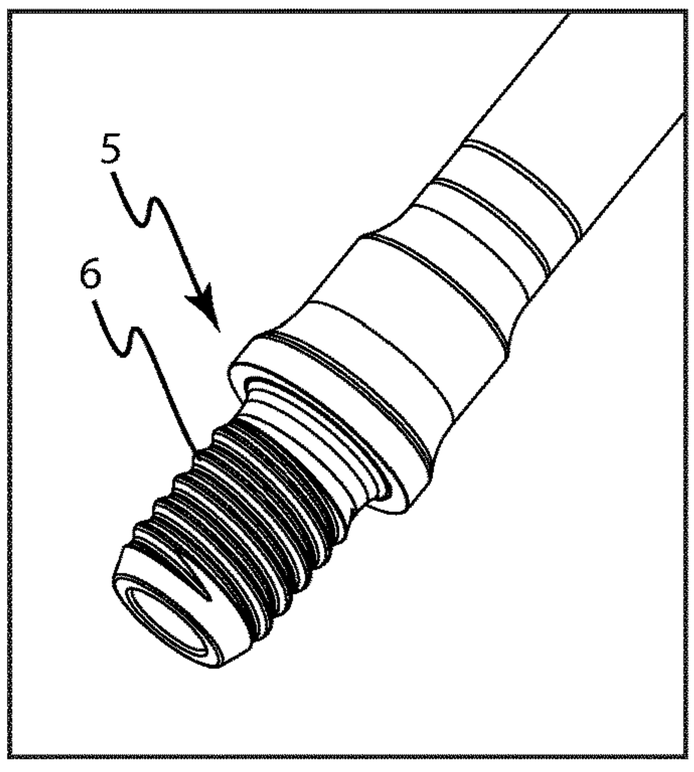
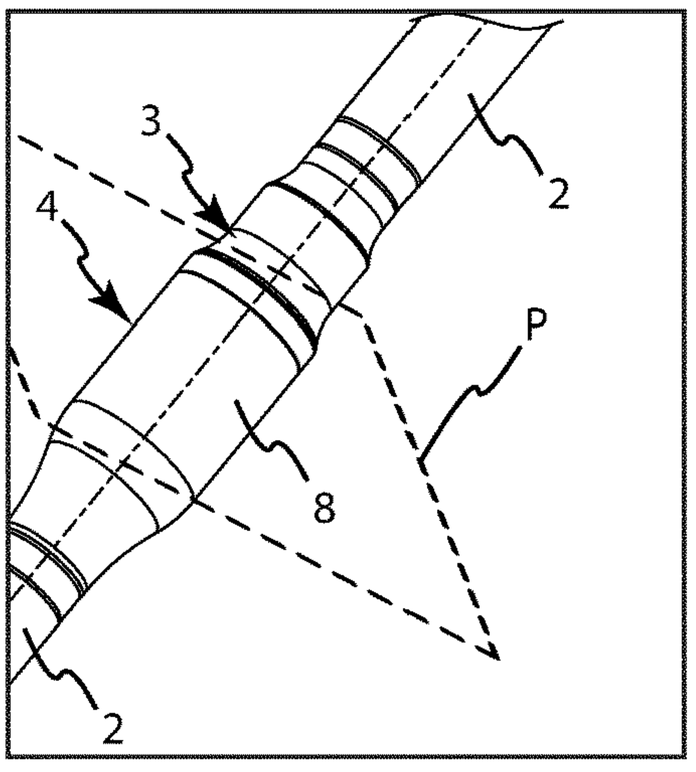


Fig. 1



A

Fig. 2



B

Fig. 3

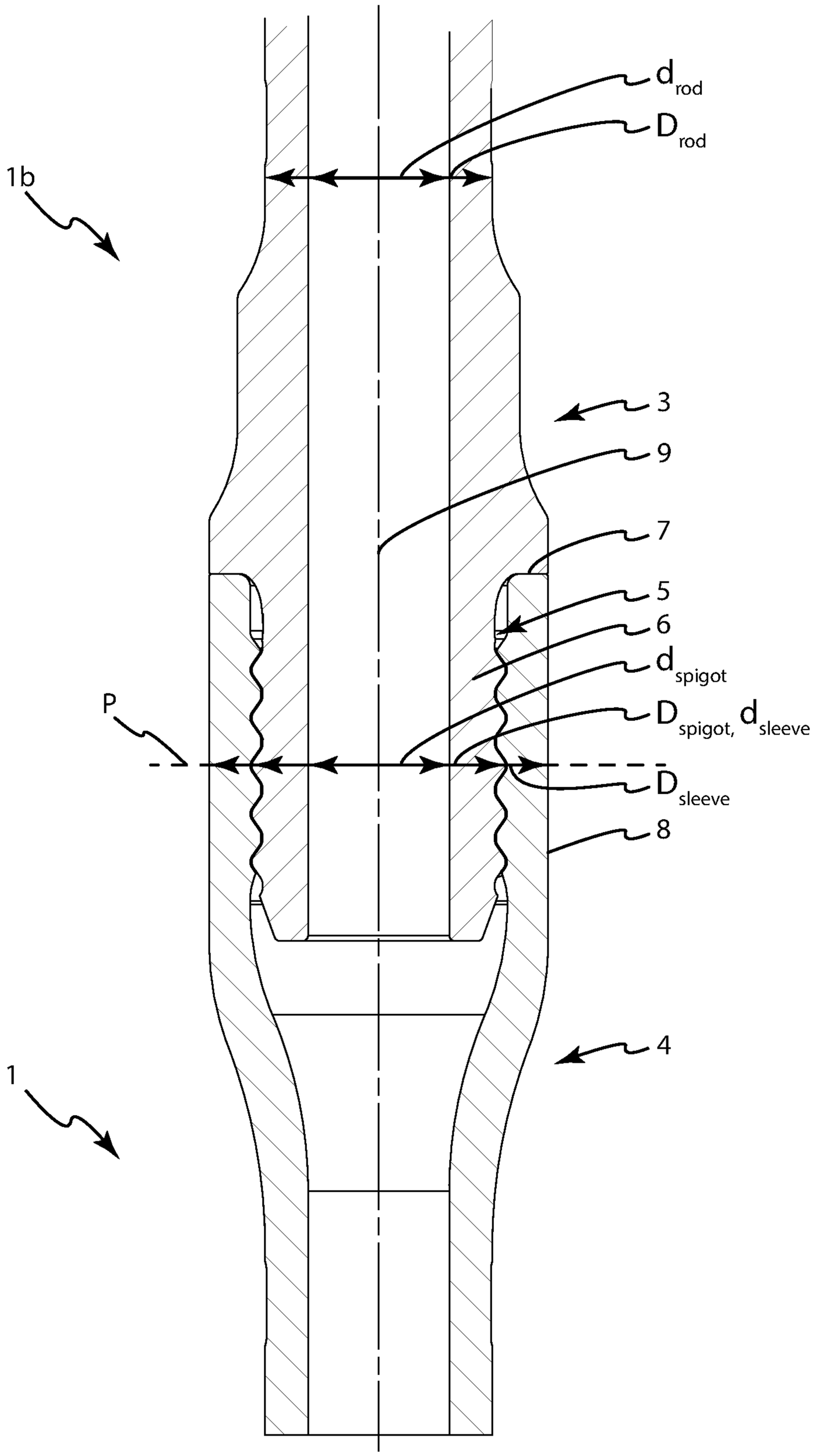


Fig. 4

DRILL STRING ROD

RELATED APPLICATION DATA

This application is a § 371 National Stage Application of PCT International Application No. PCT/EP2020/055758 filed Mar. 5, 2020 claiming priority to EP 19163477.3 filed Mar. 18, 2019.

TECHNICAL FIELD

The present invention relates to drill string rods for use with drill bits for percussion rock drilling. Specifically, the invention relates to improving the reliability and longevity of such drill string rods.

BACKGROUND

Percussion drilling is used to create a long borehole via a plurality of elongate drill string rods coupled together end-to-end by interconnected male and female threaded ends. The well-established technique breaks rock by hammering impacts transferred from a rock drill bit, mounted at one end of the drill string, to the rock at the bottom of the borehole. Typically, the energy required to break the rock is generated by a hydraulically driven piston that contacts the end of the drill string (via a shank adaptor) to create a stress (or shock) wave that propagates through the drill string and ultimately to the rock. Conventional male and female threaded couplings are described in U.S. Pat. Nos. 4,332,502; 4,398,756; 4,687,368 and DE 2800887.

The male and female threaded ends of neighboring drill rods are coupled to create the drill string and the joint is typically subjected to large forces during drilling. These forces fatigue the coupling and lead to wear and breakage within the threaded portion of the joint. Typically, it is the threaded male spigot that is damaged and determines the operational lifetime of the coupling. U.S. Pat. No. 6,767,156 discloses a threaded joint between two percussive drill rods having conical guiding surfaces provided at the leading axial ends of the male and female portions in an attempt to achieve a secure coupling and prevent damage to the threads.

EP2845992B1 by the present applicant aims to mitigate the above-mentioned drawbacks.

Modern rock drilling increasingly demands drilling of larger holes and therefore a demand exists for provision of drill strings capable of handling larger drill bits, such as drill bits with a diameter of 130 mm and larger. Conventional drill string rods are too weak to carry larger drill bits and it has shown that merely up-scaling conventional drill string rods is not an option since they tend to crack in the spigot or in the sleeve portion rather than permitting use until the threads of the spigot/sleeve portion are worn out.

Hence, there is a need for a large-size drill string rod with improved reliability and longevity, still allowing for efficient flushing of drill cuttings.

SUMMARY

An object of the invention is to provide a drill string rod enabling use of larger-than-normal percussion drill bits with improved reliability and longevity of the drill string rods. The drill string rod is to form part of an assembly of connected such drill string rods. The drill string rod comprises an elongate central rod portion extending axially between a male end and a female end. The central rod portion is hollow-cylindrical defined by an inner first diameter (d_{rod}) and an outer second diameter (D_{rod}). The male end comprises a spigot, wherein the spigot comprises a base projecting axially from a shoulder that axially separates the spigot and the central rod portion. The female end comprises a sleeve portion configured to fit to the spigot. Also, the base is provided with an outer thread and the sleeve portion is provided with an inner thread, wherein the inner thread corresponds to the outer thread such that the inner thread of the sleeve portion is attachable to the outer thread of the base of the spigot of a further drill string rod of the assembly. In a radial plane to the longitudinal axis of the drill string rod, the base of the spigot is defined by an outer third diameter (D_{spigot}) and an inner fourth diameter (d_{spigot}) and the sleeve portion is defined by an outer fifth diameter (D_{sleeve}) and an inner sixth diameter (d_{sleeve}). The present invention is limited to drill string rods with an outer second diameter (D_{rod}) larger than 60 mm, thus being suitable for use with larger and heavier percussion drill bits. C_{sleeve} and C_{spigot} are related to the diameters of the drill string rod as defined by the following formulas:

$$C_{sleeve} = \frac{D_{rod} \cdot \left(D_{sleeve}^4 - d_{sleeve}^4\right)}{D_{sleeve} \cdot \left(D_{rod}^4 - d_{rod}^4\right)}$$

$$C_{spigot} = \frac{D_{rod} \cdot \left(D_{spigot}^4 - d_{spigot}^4\right)}{D_{spigot} \cdot \left(D_{rod}^4 - d_{rod}^4\right)}$$

C_{sleeve} should be larger than 2.31 or C_{spigot} should be larger than >0.68.

Drill string rods and their use are known in the art. However, drill string rods with an outer diameter D_{rod} larger than 60 mm are not common. These larger drill string rods are very robust and suitable for larger rock drill bits. While normal drill string rods with rod diameter smaller than 60 mm tend not to have material failures but to be discarded and replaced only when the threads of the spigot and sleeve portion are worn out, larger diameter drill rods tend to break by cracks in the sleeve portion or spigot. Mitigating formation of cracks merely by increasing the thickness of goods is generally not successful, since it would either weaken some other part of the drill rod or reduce available space for flushing fluid and drill cuttings to move through. The skilled person understands that the diameters cannot be chosen freely. For example, the outer diameter of the spigot is naturally limited by the inner diameter of the sleeve portion. Also, the outer diameter of the sleeve portion is typically limited by the size of the bore drilled and the requirement for enough space for the flushing away of drill cuttings past the sleeve portion between the sleeve portion and the inner wall of the bore. Similarly, the inner diameter of the spigot limits the rate at which flushing fluid can be pumped through the drill string rod, and thus should not be too small. The design of these large-diameter drill string rods is clearly a difficult balancing act and the present invention guides the skilled person to the selection of a combination of parameters enabling reduced risk of material failures in the drill string rod with sustained flushing performance. To solve this problem has shown to be more difficult than it would seem.

The inventors of the present invention have realized that the drill string rod failures are due to the combination of the increased stiffness of the central rod portion and forced bending of the drill string induced by harder layers or cracks in the rock. The bending of the drill string rod happens while the rod is rotating and thereby creates both additional stress

due to bending, and fatigue due to the constant change of bending axis caused by the rotation of the rod in the bore whilst in its bent condition.

The proposed solution is to dimension the spigot and the sleeve portion such that the calculated maximum bending stress in the spigot and the sleeve portion respectively is related to the calculated maximum bending stress in the central rod portion. However, the inventors have realized that the calculated maximum stresses of the sleeve portion and the spigot respectively should not be equal to the calculated maximum bending stress of the central rod portion but rather relate to the calculated maximum bending stress of the central rod portion multiplied by the factor C_{sleeve} or C_{spigot}, respectively, in order to account for commonly occurring differences in strength occurring for example due to local material variations likely occurring due to uneven hardening and/or machining at manufacturing of the drill string rods.

In some embodiments, C_{sleeve} >2.31 and C_{spigot} >0.68. This balance of the first, second, third, fourth, fifth, and sixth diameters involved provide for high reliability and longevity of the drill string rod.

In some embodiments, the base of the spigot is conical.

In some embodiments, the base of the spigot is cylindrical.

In some embodiments, the first diameter (d_{rod}) is 50 mm, wherein the second diameter (D_{rod}) is 80.5 mm, wherein the third diameter is (D_{spigot}) is 82 mm, wherein the fourth diameter (d_{spigot}) is 50 mm, wherein the firth diameter is (D_{sleeve}) is 120 mm and wherein the sixth diameter (d_{sleeve}) is 91.2 mm.

In some embodiments, the drill string rod is suitable for use with a drill bit having an outer seventh diameter (D_{hole}), wherein the fifth diameter is <0.90* the seventh diameter (D_{hole}).

A further aspect relates to a system comprising a plurality of drill string rods according to the first aspect described above.

In some embodiments, the drill string rods of the system are of the type mentioned above which are suitable for use with a drill bit having an outer seventh diameter (D_{hole}), wherein the fifth diameter is <0.90* the seventh diameter (D_{hole}), and wherein the system further comprises the drill bit.

The difference in diameter between the hole and the outer diameter of the sleeve portion enables efficient flushing of drill cuttings past the sleeve portion, whilst providing robust drill string rods capable of handling the forces involved.

In some embodiments, the seventh diameter is >130 mm. Drill string rods having a second diameter >60 mm are suitable for such large-diameter drill bits, wherein the specified constraints of the involved diameters of the drill string rods governed by C_{sleeve} and C_{spigot} provide for a robust drilling system.

DESCRIPTION OF DRAWINGS

FIG. **1** shows a perspective view of two identical connected drill string rods.

FIG. **2** shows an enlarged perspective view A of the male end of the drill string rod as indicated in FIG. **1**.

FIG. **3** shows an enlarged perspective view B of the female end of the drill string rod as indicated in FIG. **1**, which is connected to the male end of the other drill string rod.

FIG. **4** shows a cross-sectional side view of the sleeve portion and the spigot of the two connected drill string rods also shown in FIG. **1**, said cross-section taken in a plane through the longitudinal central axis of the drill string rod.

DETAILED DESCRIPTION

A first embodiment of the invention is shown in FIGS. **1-4**. As shown in the figures, a plurality of identical drill string rods **1**, **1***b* are connectable to form a system/assembly **10**. The drill string rod **1** comprises an elongate central rod portion **2** extending axially between a male end **3** and a female end **4**. As shown in FIG. **4**, the central rod portion **2** is hollow-cylindrical defined by an inner first diameter d_{rod} and an outer second diameter D_{rod}. The male end **3** comprises a spigot **5**, and the spigot **5** comprises a base **6**

$$C_{sleeve} = \frac{D_{rod} \cdot \left(D_{sleeve}^4 - d_{sleeve}^4\right)}{D_{sleeve} \cdot \left(D_{rod}^4 - d_{rod}^4\right)}$$

projecting axially from a shoulder **7** that axially separates the spigot **5** and the central rod portion **2**. The female end **4** comprises a sleeve/sleeve portion **8** configured to fit to the spigot **5**. The base **6** is provided with an outer thread and the sleeve portion **8** is provided with an inner thread, wherein the inner thread corresponds to the outer thread such that the inner thread of the sleeve portion **8** is attachable to the outer thread of the base **6** of the spigot **5** of a further drill string rod of the assembly. In a radial plane P to the longitudinal axis of the drill string rod the base **6** of the spigot **5** is defined by an outer third diameter (D_{spigot}) and an inner fourth diameter (d_{spigot}) and the sleeve portion **8** is defined by an outer fifth diameter (D_{sleeve}) and an inner sixth diameter (d_{sleeve}). It should be noted that in FIG. **4**, D_{spigot} and d_{sleeve} are both mentioned in connection with the same arrow although in reality the diameters are slightly different with d_{sleeve} being larger than D_{spigot}. The scale of the drawing is such that the difference in diameter cannot be shown in FIG. **4** using separate arrows. Although the diameters may vary along the length of the spigot and the sleeve portion respectively, the radial plane P which by necessity runs through both the spigot and the sleeve portion, is used to define the relationship between the diameters in an unambiguous way.

$$C_{spigot} = \frac{D_{rod} \cdot \left(D_{spigot}^4 - d_{spigot}^4\right)}{D_{spigot} \cdot \left(D_{rod}^4 - d_{rod}^4\right)}$$

The present invention is limited to drill string rods with an outer diameter larger than 60 mm, thus being suitable for use with heavier percussion drill bits, such as drill bits larger with larger diameter than 130 mm. Hence, the second diameter (D_{rod}) is >60 mm. C_{sleeve} and C_{spigot} are derivable from/related to the diameters of the drill string rod using the following formulas:

These formulas stem from the calculation of section modulus for a known hollow-cylindrical beams/bodies which provide a good approximation of the present involved cross-sectional shapes. Specifically, the section modulus equations for hollow-cylindrical cross-sections is:

$$S = \frac{\pi\left(r_2^4 - r_1^4\right)}{4r_2} = \frac{\pi\left(d_2^4 - d_1^4\right)}{32d_2}$$

Our assumption is that:

$$S_{spigot} = C_{spigot} * S_{rod} \rightarrow \frac{\pi\left(D_{spigot}^4 - d_{spigot}^4\right)}{32 * D_{spigot} \cdot} = \frac{\pi\left(D_{rod}^4 - d_{rod}^4\right)}{32 * Drod} * C_{spigot} \rightarrow$$

$$\rightarrow C_{spigot} = \frac{D_{rod} \cdot \left(D_{spigot}^4 - d_{spigot}^4\right)}{D_{spigot} \cdot \left(D_{rod}^4 - d_{rod}^4\right)}$$

And similarly that $S_{sleeve}=C_{sleeve}*S_{rod}\rightarrow$

$$\rightarrow C_{sleeve} = \frac{D_{rod} \cdot \left(D_{sleeve}^4 - d_{sleeve}^4\right)}{D_{sleeve} \cdot \left(D_{rod}^4 - d_{rod}^4\right)}$$

In this embodiment, the first diameter d_{rod} is 50 mm, wherein the second diameter D_{rod} is 80.5 mm, wherein the third diameter D_{spigot} is 82 mm, wherein the fourth diameter d_{spigot} is 50 mm, wherein the fifth diameter D_{sleeve} is 120 mm and wherein the sixth diameter d_{sleeve} is 91.2 mm.

This embodiment of the drill string rod **1**, **1***b* is suitable for use with a drill bit (not illustrated) having a specified diameter (the diameter not including the drilling inserts) of 140, 152, 165, 172 or 178 mm. The actual diameter of the holes drilled is slightly larger since the drill bits protrude radially. The first through sixth diameters may in other embodiments be chosen differently, as long as the second diameter D_{rod}, which defines the outer diameter of the central rod portion **2**, fulfills the above constraint of being at least 60 mm, and the other diameters fulfil the constraints that C_{sleeve} is larger than 2.31 or that C_{spigot} is larger than 0.68. Preferably, C_{sleeve} is larger than 2.31 and C_{spigot} is larger than 0.68.

The drill string rods are made of a suitable material, such as steel, and are hardened as needed.

The drill string rod **1**, **1***b* is dimensioned based on the size of the drill bit for which it is to be used. However, care must be taken to provide enough space around the sleeve portion **8** for drill cuttings to be flushed past the sleeve portion **8**. To this effect, the drill string rod **1**, **1***b* may in some embodiments be suitable for use with a drill bit having an outer seventh diameter D_{hole}, wherein the outer fifth diameter D_{sleeve} of the sleeve portion **8** is less than 0.90* the seventh diameter D_{hole}.

A plurality of identical drill string rods **1**, **1***b* may be provided together as part of a system/assembly **10** of the drill string rods **1**, **1***b*. The system **10** may alternatively comprise a drill bit. The drill string rods **1**, **1***b* of the system may have an outer seventh diameter D_{hole}, wherein the fifth diameter is <0.90* the seventh diameter D_{hole}, and wherein the system further comprises the drill bit.

The difference in diameter between the hole and the outer fifth diameter D_{sleeve} of the sleeve portion **8** enables efficient flushing of drill cuttings past the sleeve portion **8**, whilst providing robust drill string rods **1**, **1***b* capable of handling the forces involved.

In some embodiments, the seventh diameter D_{hole} may be 130 mm or greater. As mentioned above, the drill string rods of the present invention all have a second diameter greater than 60 mm and are suitable for such large-diameter drill bits. The specified constraints of the involved diameters given by C_{sleeve} and C_{spigot} provide for a robust system/assembly **10**.

The invention claimed is:

1. A drill string rod arranged to form part of an assembly of connected drill string rods, the drill string rod comprising:

an elongate central rod portion extending axially between a male end and a female end, wherein the central rod portion has a hollow-cylindrical shape defined by an inner first diameter (d_{rod}) and an outer second diameter (D_{rod}), wherein the male end includes a spigot, the spigot having a base projecting axially from a shoulder that axially separates the spigot and the central rod portion, wherein the female end includes a sleeve portion configured to fit to the spigot, wherein the base is provided with an outer thread and wherein the sleeve portion is provided with an inner thread, wherein the inner thread corresponds to the outer thread such that the inner thread of the sleeve portion is attachable to the outer thread of the base of the spigot of a further drill string rod of the assembly, a connection between the inner thread of the sleeve portion and the outer thread of the base being cylindrical, wherein, in a radial plane to the longitudinal axis of the drill string rod, the base of the spigot is defined by an outer third diameter (D_{spigot}) and an inner fourth diameter (d_{spigot}) and the sleeve portion is defined by an outer fifth diameter (D_{sleeve}) and an inner sixth diameter (d_{sleeve}), wherein the second diameter (D_{rod}) >60 mm, wherein a relationship between outer diameters of the sleeve (C_{sleeve}) and a relationship between outer diameters of the spigot (C_{spigot}) are defined as:

$$C_{sleeve} = \frac{D_{rod} \cdot \left(D_{sleeve}^4 - d_{sleeve}^4\right)}{D_{sleeve} \cdot \left(D_{rod}^4 - d_{rod}^4\right)}$$

$$C_{spigot} = \frac{D_{rod} \cdot \left(D_{spigot}^4 - d_{spigot}^4\right)}{D_{spigot} \cdot \left(D_{rod}^4 - d_{rod}^4\right)}$$

and wherein C_{sleeve} >2.31 or C_{spigot} >0.68, wherein a radial plane P extends through both the spigot and the sleeve portion along an entire length of the connection and defines the relationship between the outer diameters of the sleeve (C_{sleeve}) and the relationship between outer diameters of the spigot (C_{spigot}).

2. The drill string rod according to claim **1**, wherein C_{sleeve} >2.31 and C_{spigot} >0.68.

3. The drill string rod according to claim **1**, wherein the base of the spigot is conical.

4. The drill string rod according to claim **1**, wherein the first diameter (d_{rod}) is 50 mm, wherein the second diameter (D_{rod}) is 80.5 mm, wherein the third diameter (D_{spigot}) is 82 mm, wherein the fourth diameter (d_{spigot}) is 50 mm, wherein the fifth diameter (D_{sleeve}) is 120 mm and wherein the sixth diameter (d_{sleeve}) is 91.2 mm.

5. The drill string rod according claim **1**, wherein the drill string rod is arranged for use with a drill bit having an outer seventh diameter (D_{hole}), wherein the fifth diameter (D_{sleeve}) is <0.90* the seventh diameter (D_{hole}).

6. A system comprising a plurality of drill string rods according to claim **1**.

7. The system according to claim **6**, wherein said system includes a drill bit, the drill string rod being arranged for use with the drill bit, the drill bit having an outer seventh diameter (D_{hole}), wherein the fifth diameter (D_{sleeve}) is <0.90* the seventh diameter (D_{hole}).

8. The system according to claim **7**, wherein the seventh diameter (D_{hole}) is 130 mm or larger.

* * * * *